

Bernard, Claude

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Claude Bernard (1818-1878)

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Fiorenzo Conti

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Claude Bernard (Figure 1) was born on 12 July 1813 in Saint-Julien de Villefranche, in the French region of Beaujolais. After a first course of private studies, he attended the Jesuits' colleges of Villefranche and Thoissey, where he was taught literature but no physics or natural sciences.

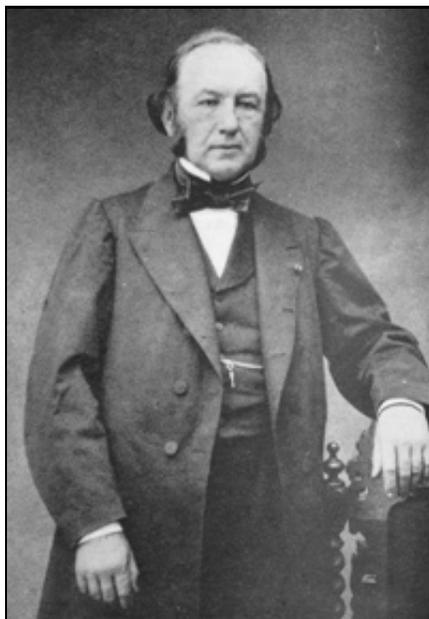


Figure 1: Claude Bernard.

Due to family financial problems, he had to abandon his studies and was hired by a Lyon chemist. At this time he also started an intense literary activity that led first to the writing of a vaudeville entitled *Rose du Rhône* and subsequently of a historical tragedy, *Arthur de Bretagne*. Determined to pursue his literary ambitions, Bernard moved to Paris, where he hoped that the editor Saint-Marc Girardin, a fellow Burgundian, would publish his work. Girardin, however, advised the young dreamer to learn a job: thus started the career of the man who eventually changed physiology

and medicine for ever! Bernard began medical studies and a few years later he came into contact with François Magendie and soon became his favourite *préparateur* (research assistant). He became a medical doctor in 1843, but failed the examination that would have qualified him to teach in the medical school and was forced to earn a living in the private laboratory of Dr Theodore-Jules Pelouze, a friend of Magendie. So that he could continue his research, he married the daughter of a wealthy woman, Marie-Françoise Martin. From 1847 his scientific life became a continuous succession of studies, publications and honours.

Bernard's physiology rests on three conceptual pillars: determinism, the rejection of teleology and metaphysics, and the overcoming of dependence on anatomy. Bernard inherited determinism from the two preceding centuries and placed it at the heart of his physiology. His determinism was "absolute", first because it concerned both inanimate objects and living organisms; secondly because a phenomenon will not occur differently given the same conditions; and thirdly because it also applied to the psychic sphere. Bernard thus appropriated the teachings of natural sciences and laid the foundations of much of the subsequent evolution of life sciences. Bernard's absolute determinism entailed relinquishing the teleological and metaphysical tendency of physiology, and transformed it from the science of seeking the "whys" into that of studying the "hows".

By shrinking the scope of physiology, Bernard paved the way for the century and a half of extraordinary progress that so profoundly affected both scientific knowledge and medical practice. The concept that physiological phenomena depend on physico-chemical causes inevitably entailed the overcoming of the concept of physiology as "anatomy in motion" (*anatomia animata*) and a radical shift in perspective. From these considerations stems Bernard's concept of *milieu intérieur*: he emphasized that an animal's life depends on the internal environment, that is, on the plasma (extracellular fluids), which provides the physico-chemical conditions for the correct functioning of cells. Bernard reasoned that if correct cell functioning depends on optimal physico-chemical conditions, then these must be constant and, inevitably, there have to be mechanisms that allow such conditions to be maintained. More than sixty years later, Walter Cannon was to broaden this concept and call it homeostasis. Since then, a large portion of life sciences has been pivoting on this concept, and it is difficult to imagine any function of the organism without making reference to homeostatic mechanisms. In Bernard's opinion, the "new" life sciences needed to penetrate the internal environment and investigate its regulation if they were to study living organisms. To him, this meant animal experimentation (Figure 2). Although animal experiments had been done since antiquity, Bernard established them as an essential tool in the acquisition of physiological and clinical data. His conviction that the study of living creatures is a precondition of understanding the functioning and dysfunction of organs and organisms influenced generations of scientists and physicians and greatly contributed towards one of the richest periods in the history of biomedical sciences.

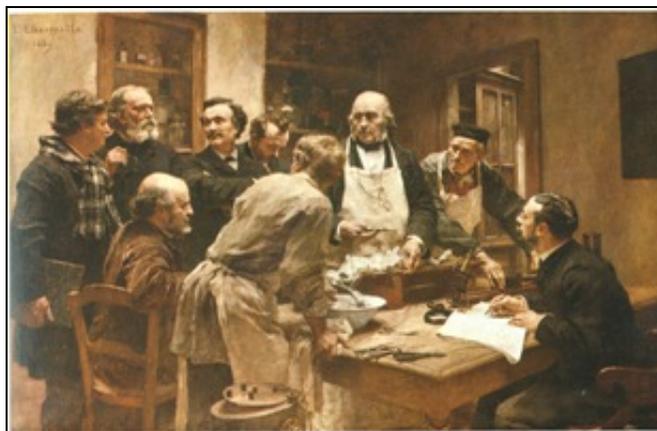


Figure 2: Acquiring data through animal experimentation.

The name of Bernard is inextricably linked to the experimental method, which is discussed in his well-known *Introduction à l'étude de la médecine expérimentale* (Figure 3). Although this association is not entirely correct, and Bernard himself rejected the attribution of its discovery, it

is nonetheless true that he crowned the experience of the two previous centuries and added two characteristic elements of his epistemological creed: the emphasis on the concept of hypothesis and fallibilism.

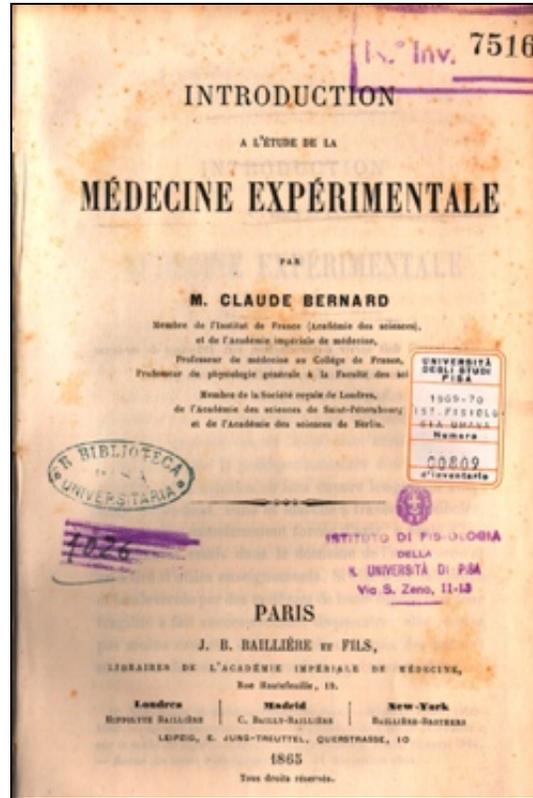


Figure 3: From Bernard's *Introduction à l'étude de la médecine expérimentale*.

According to Bernard, the experimental method rests on the sequence of events from observation through hypothesis to experiment. Observation and experiment are not different in nature, but for their position within the sequence. The experiment is an observation performed with a view to verifying a hypothesis: by providing facts to the experimenter it becomes in turn an observation (and the starting point of another sequence). Thus, the logic of experimental reasoning is circular. Like nobody before him, Bernard emphasized the need for experiments to rest on experimental reasoning deriving from a hypothesis. But Bernard, educated at the school of the empiricist François Magendie, knew that a researcher often has to deal with things about which he knows no "fact" beforehand. In such cases, an "exploratory experiment" (*expérience pour voir*) needs to be done. This becomes the starting point for advancing a hypothesis, which is then subjected to experimental verification. A fundamental feature of Bernard's methodological conception is the fallibility of all theories.

Bernard's neurological studies have been collected in the *Leçons sur la Physiologie et la Pathologie du Système Nerveux* (Figure 4) and in the *Leçons sur les Effets des Substances Toxiques et Médicamenteuses*. Bernard carried out the bulk of his early neurological studies along the lines traced by Magendie and shared both Magendie's experimental approach (ablations, lesions, use of poisons) and conceptual bases (close bonds with clinical and pathological studies). An example is his research into recurrent sensitivity: Magendie had observed that pinching or cutting the ventral roots in dogs resulted in pain-like responses and that resection of the appropriate dorsal root abolished these responses, a phenomenon for which he coined the term "recurrent sensitivity" (which seems to depend on unmyelinated fibres of the ventral root that carry nociceptive information to the dorsal horn through the dorsal root). Recurrent sensitivity became a popular subject of investigation and generated many controversies; Bernard performed many experiments on it and resolved its ostensible contradictions by researching in great detail the experimental conditions required for its expression.

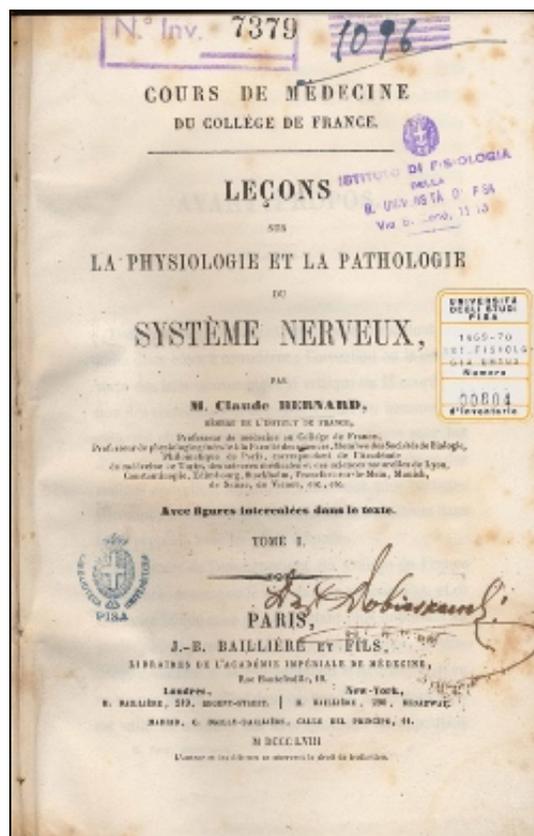


Figure 4: From Bernard's *Leçons sur la Physiologie et la Pathologie du Système Nerveux*.

At least two of Bernard's neurological contributions have had a crucial influence in shaping our understanding of the brain's functions: the emphasis on the role played by the central nervous system in the regulation of vital functions and the curare studies.

Life and the brain. In his opening lecture of the 1856-1857 Course at the Collège de France, Bernard stated that he considered the regulation of vital functions (the first chapter of his *Leçons sur la Physiologie et la Pathologie du Système Nerveux*) as the foremost function of the brain. He wrote: "It is [the brain] that activates and regulates not only all the phenomena of our everyday life, but also influences all the events of organic life, all the acts related to nourishment, secretion, heat production, etc ... There is no longer any doubt today of the truth of this role: in fact, by acting on the nervous system we can modify not only the actions of everyday life, but also the phenomena of secretion and thermogenesis; these, though being physico-chemical phenomena, are closely influenced by the nervous system." (It was in the course of these investigations that Bernard noted an appreciable temperature increase in the affected region following resection of the cervical sympathetic chain: this resulted in the attribution to him of the discovery of vasomotor fibres, even though his initial interpretation of this phenomenon was in fact incorrect.) In this context, it is fascinating to consider that, historically, the relationship between life and nervous system function has tended to be neglected or considered at best of secondary importance. However, according to recent theories, it is in the sum of the nervous mechanisms governing the regulation of the milieu intérieur that neural patterns of functions, organs and also of body delimitation become organized during evolution (creating the self) and thus where the origin of consciousness should be sought.

The action of curare. Bernard showed that electrical stimulation of a motor nerve in a curarized frog does not elicit muscular contractions even if the muscle is still capable of contracting if stimulated directly; that curare has no action on sensation; that stimulating a sciatic nerve soaked in curare provokes normal muscular contraction if the muscle is outside the curare bath, whereas stimulating the sciatic nerve lying outside the curare bath does not elicit contractions if the muscle is soaked in the curare bath; and that injection of curare into the artery supplying a muscle (Figure 5) provokes its paralysis. His numerous curare experiments contributed to the

hypothesis that some structure exists between the nervous motor fibres and the striated muscle fibres with properties differing from those of either. Bernard had indeed some intuition of the existence of such a structure as he wrote: "curare must act on the terminal plates of motor nerves" and "Curare does no more than interrupt something motor which puts the nerve and the muscle into electrical relationship for movement; "motor" is not quite clear but probably refers to the activating agent, the one we now call "motor nerve impulse". The neuromuscular synapse was eventually described in the early 1860s by a former student of Bernard's, W. F. Kühne (1837-1900), and by W. Krause (1833-1910), and more exhaustively in Kühne's 1888 Croonian Lecture. By forging new ideas regarding cell-to-cell communication, as well as by its direct influence, this discovery paved the way for the foundation of the neuron doctrine and heralded the "synaptic era".

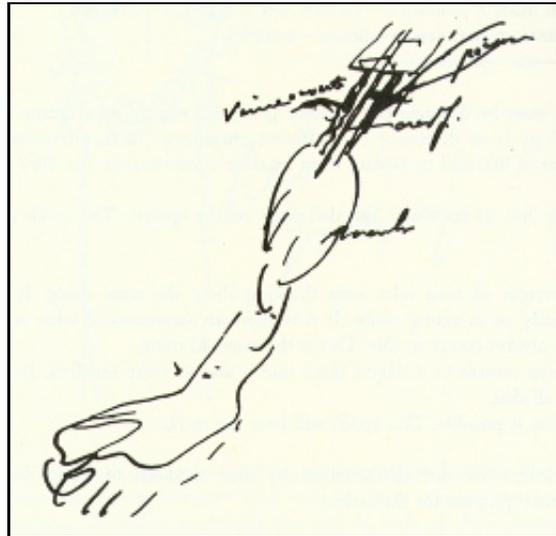


Figure 5: Injection of curare into the artery supplying a muscle provokes its paralysis.

A little-known article by Bernard entitled *Des Fonctions du Cerveau* appeared in the 15 March 1872 issue of the periodical *Revue des Deux Mondes* (Figure 6), in which he elaborated some concepts addressed in his *Discours pour la reception* in the Académie Française three years earlier.

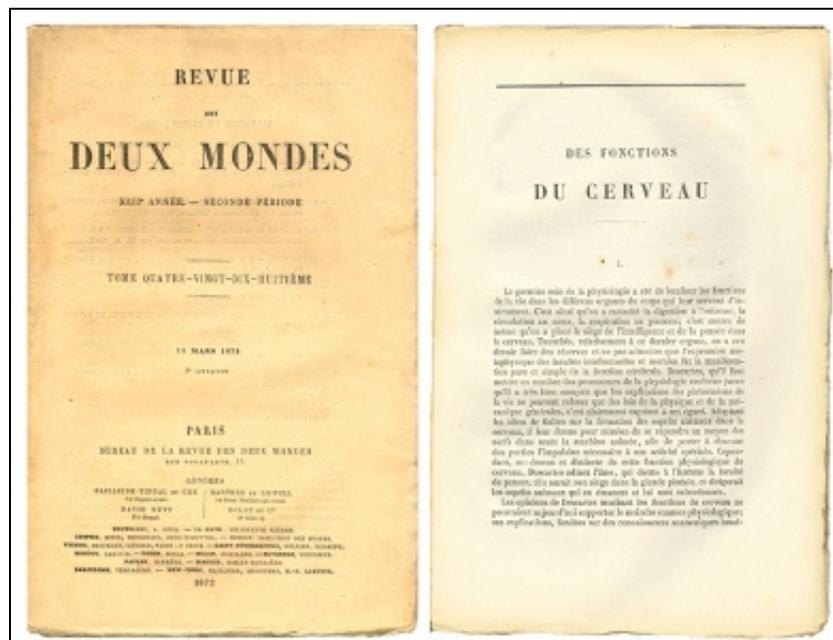


Figure 6: Bernard's *Des Fonctions du Cerveau* (1872).

At variance with many of his *Leçons*, which are not an easy read today, *Des Fonctions du Cerveau* is exceptionally modern in both content and language. In essence, *Des fonctions* deals with a refusal to accept the view that thought, intelligence and higher brain functions are beyond the realm of experimentation. As a physiologist convinced of the power of experimentation and direct observation, Bernard rejects the idea that brain function will not yield to experimental research.

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Favourite sentences

1. On determinism:

"To us, physiology is thus the science that aims at studying the phenomena of living beings and at defining the material conditions that determine their manifestation ... once the conditions determining a phenomenon are known, the same phenomenon must be reproducible by the experimenter at will ... This is an absolute principle governing both living organisms and inanimate objects" (Bernard, 1865).

2. On "why" and "how":

"The nature of our spirit drives us to seek the essence or the reason of things, so we tend to look farther than the object of our quest ... Yet, we cannot go beyond the how, that is to say beyond the near causes or the conditions of the existence of phenomena ... What is true is that the nature or the very essence of all phenomena, be they vital or mineral, will forever remain unknown to us ... Science has precisely the privilege of making us know what we ignore, substituting reason and experience to feeling, and showing clearly the boundaries of our present knowledge. But, by virtue of a wonderful compensation, as science humbles our pride, it strengthens our power . . . To sum up, if our feeling daily asks "why", our reason shows that only "how" is within our reach; for the present, it is thus only the how that interests the scientist and the experimenter" (Bernard, 1938).

3. On anatomy:

"Galen performed both corpse dissections and experiments on live animals, a demonstration that he too perfectly understood that the former are interesting only insofar as they can be compared with the latter ... The humoral or physico-chemical part of physiology, which cannot be dissected and constitutes what we define as our internal environment has been neglected and overlooked ... Indeed, when an anatomist observes in a part of the body some muscle fibres, he concludes that there is muscle contraction; when he observes gland cells he concludes that there is secretion; when he sees nerve fibres that there is sensitivity and movement. But how did he learn that muscle fibres contract, gland cells secrete and nerves are sensory or motor if not by studying living organisms?" (Bernard, 1865).

4. On the constancy of the milieu intérieur:

"The constancy of the internal environment is the element conditioning free, independent life: the mechanism that makes it possible is in fact the same that ensures the maintenance in the internal environment of all the conditions required for the life of the elements" (Bernard, 1878-1879).

5. On the experimental method:

"The complete scientist is one who masters both theory and experimental practice. 1, he observes a fact; 2, he conceives an idea with reference to this fact; 3, on the basis of this idea he pursues

a line of reasoning, plans an experiment and imagines and organizes its material conditions; 4, this experiment produces more phenomena that shall be subjected to observation and so on. In a sense, the scientist's mind is always between two observations: one is the starting point of the reasoning, the other its conclusion" (Bernard, 1865).

6. *On the fallibility of theories:*

"The main characteristic that a scientist studying natural phenomena must have is complete freedom of the spirit based on philosophical doubt ... When we conceive a general scientific theory, the one thing of which we can be certain is that - speaking in absolute terms - all such theories are false. They are but partial and provisional truths that we need, like steps on which we rest, to advance in our investigation." And "If an idea arises, we should not reject it only because it does not agree with the logical consequences of a dominant theory" (Bernard, 1865).

7. *On the experimental medicine:*

"I consider hospitals as the anteroom of scientific medicine; they certainly are the first field of observation for the physician, but the sanctuary of medical science is the laboratory: it is here that by means of experimental analysis the researcher seeks the explanations on the nature of vital phenomena in normal and pathological conditions" (Bernard, 1865).

8. *On the brain:*

"How can it be that physiologists are able to explain the phenomena that take place in all of the body's organs but only a fraction of those that happen in the brain? It is impossible for such distinctions to exist among the vital phenomena. Admittedly, these phenomena are endowed with different degrees of complexity, but either they are all accessible, or they are all inaccessible to our study, and the brain, however wonderful the metaphysical manifestations of which it is the seat appear to us, can certainly not be the sole exception" (Bernard, 1872).

9. " ... brain physiology must be inferred from anatomical observations, physiological experiments, and the knowledge of pathological anatomy exactly like that of all the other body organs." And, "If we now consider the organic and physico-chemical conditions essential for life and the execution of functions, we can see that they are identical in the brain and in all the other organs" (Bernard, 1872).

10. "Diseases, which ultimately are nothing more than vital perturbations brought about by nature rather than the hand of the physiologist, affect the brain according to the common laws of pathology, that is to say, by giving rise to functional disturbances that are always connected with the nature and the site of the lesion" (Bernard, 1872).

11. "We believe that the advances of modern science do allow us to take on the physiology of the brain" (Bernard, 1872).

12. "Physiology demonstrates that, accounting for the different and more complex nature of the relevant phenomena, the brain is the organ of intelligence exactly like the heart is the organ of circulation and the larynx is the organ of voice" (Bernard, 1872).

13. *The best:*

"I am convinced that when physiology shall be sufficiently advanced, the poet, the philosopher and the physiologist will understand each other" (Bernard, 1865).

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